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THE DESIGN, CONSTRUCTION AND TESTING OF AN ARCTIC SURVIVAL SLED

for

Transportation Development Centre
Suite 601, West Tower
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Montreal, Quebec
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by

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LANGUAGE NOTICE

Un sommaire en français de ce rapport est inclus avant la Table des matières.

PROJECT TEAM

For Melville Shipping Ltd.:

- R. A. Dick
- M. Kalisiak

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16. Abstract

This report documents the design, construction and testing of an Arctic survival sled developed to transport lifesaving and survival equipment from a ship, over water and ice, to a safe location to set up a survival camp. The sled was designed to accommodate the weight and volume of an Arctic survival pack, to be dropped from a ship, and to be towed through water and over a range of ice conditions.

A prototype of the sled performed well in all tests but had several deficiencies, the paramount being excessive weight and strength, and the secondary being susceptibility to minor leakage and damage to the seal latches. In a second-generation design, the strength and volume would be reduced and the hemispherical seal and associated latches would be replaced with top and bottom mounted access latches.

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16. Résumé

Ce rapport traite de la conception, de la réalisation et de l'essai d'un traîneau de survie destiné à l'Arctique, et mis au point en vue de transporter le matériel de survie, dans l'eau et sur la glace, depuis un navire jusqu'à un endroit sûr où établir un camp de survie. Le traîneau a été conçu en fonction du poids et du volume du matériel de survie nécessaire dans l'Arctique, et afin de pouvoir être lancé d'un navire et remorqué dans l'eau et sur différentes surfaces glacées.

Un prototype du traîneau s'est bien comporté lors des essais; toutefois, il présentait plusieurs défauts: le plus important étant un poids beaucoup trop élevé et une construction inutilement robuste, et d'autres plus légers touchant l'étanchéité et les attaches à bascule. Dans la conception d'un traîneau de seconde génération, les matériaux seraient allégés et le volume diminué, tandis que la construction en deux demi-coquilles réunies au moyen d'attaches à bascule et joint d'étanchéité serait remplacée par une construction monocoque à trappes d'accès sur le dessus et le dessous.

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EXECUTIVE SUMMARY

The need for an Arctic survival pack was established in the report entitled "Arctic Survival Equipment Tests - 1987/88", prepared by Melville Shipping Ltd. That report reflects several years of research and two on-ice experimental programmes with groups of volunteers. However, it was recognized that transportation of the survival packs from the ship to a safe place on the ice presented many difficulties.

This report, prepared by Melville Shipping Ltd. and sponsored by the Transportation Development Centre with the support of the Canadian Coast Guard, documents the design, building and testing of an Arctic survival sled. The main points of interest are summarized below.

a) The sled was designed to meet the many requirements imposed by the weight and volume of the survival and by the need to be dropped from a ship and towed through water and ice over a range of ice conditions.

b) The carrying capacity of the sled is 1.5 m^3, sufficient for 10 people, each of whom requires about 0.15 m^3 of survival equipment.

c) The sled was constructed in two units: an upper and a lower unit with a seal between the two units. The carrying compartment is divided into three spaces, with two end compartments in each unit. The sides of the sled are constructed of 100 mm thick foam panels sheathed in fibreglass and Kevlar. The top, bottom and internal bulkheads are of plywood sheathed in fibreglass.

d) The sled was built by Fibron Industries of Ottawa and was hydrostatically tested at the Nepean Yacht Club on the Ottawa River, drop-tested at the Fednav Marine Terminal in Montreal, and functionally tested near Resolute Bay, NWT. The functional tests included handling the sled onboard the CCG JOHN A. MACDONALD, launching the sled from the ship, marshalling the sled from a workboat, towing the sled through an area of broken ice, pulling it onto a large ice flow, handling the sled over smooth and rough ice conditions and finally, repeating the drop tests as a check on the integrity of the seals.

e) The sled performed well in all tests. However, there were several deficiencies, the most important being its excessive weight, and others being susceptibility to minor leakage and damage to the seal latches. The leakage occurred only in one end compartment and could be easily corrected by adjustment of the seal latches. The latch damage occurred when the sled was being handled onboard the ship. Recessing the latches would probably prevent this damage from occurring. Complete elimination of the latches by arrangement of access plates on the top and bottom of the sled would be preferred.

f) Based on the findings of this project, a second-generation design with reduced strength, volume and weight and no hemispherical seal nor associated latches has been proposed. Access to the sled's single compartment would be arranged through top and bottom mounted access hatches. The sled's width would be maintained as before but the length and height would be greatly reduced. These changes would offer slightly less volume but would make the sled more manageable and less expensive.

The report recommends that, before further developing the sled design, the final make-up of the survival pack be determined and specified in detail.

SOMMAIRE

Le rapport intitulé "Arctic Survival Equipment Tests - 1987/88", rédigé par Melville Shipping Ltd., fait état du besoin d'une trousse de survie pour l'Arctique. Ce rapport rend compte des résultats de plusieurs années de recherche ainsi que de deux programmes expérimentaux menés en région polaire, grâce à des groupes de volontaires. Il a toutefois été constaté que le transport des équipements de survie, du navire à un endroit sécuritaire sur la glace, était très difficile.

Le présent rapport, préparé par Melville Shipping Ltd., pour le compte du Centre de développement des transports et de la Garde côtière canadienne (GCC), traite de la conception, de la réalisation et de l'essai d'un traîneau de survie destiné à l'Arctique. Les points les plus importants sont résumés ci-dessous:

a) Le traîneau a été conçu de manière à respecter les nombreuses exigences imposées par le poids et le volume des équipements de survie et par le fait qu'il devait être lancé d'un navire et remorqué dans l'eau et sur la glace dans diverses conditions.

b) Le traîneau a une capacité de rangement de 1,5 m^3, ce qui suffit au transport du matériel de survie nécessaire pour dix personnes, soit environ 0,15 m^3 de matériel par personne.

c) Le traîneau est formé de deux demi-coquilles placées l'une sur l'autre et séparées par un joint d'étanchéité. Chacune des demi-coquilles comprend un compartiment de rangement triple et deux autres compartiments d'extrémité. Les côtés du traîneau sont fabriqués de panneaux de plastique cellulaire de 100 mm d'épaisseur recouverts de fibre de verre et de Kevlar. Le dessus, le fond et les cloisons intérieures sont faits de contre-plaqué recouvert de fibre de verre.

d) Le traîneau a été fabriqué par Fibron Industries à Ottawa et soumis à des essais hydrostatiques au Club nautique de Nepean, sur la rivière Outaouais, à des essais de chute au Terminal maritime de Fednav à Montréal et à des essais in situ près de Resolute Bay dans les T.N.-O. Au cours de ces derniers essais, le traîneau a été manutentionné à bord du John A. Macdonald de la GCC, lancé à la mer, manoeuvré à partir d'un canot de service, remorqué dans une zone de glaces flottantes, hissé sur une banquise, traîné sur des surfaces glacées tantôt unies tantôt tourmentées et, enfin, soumis à de nouveaux essais de chute afin de vérifier l'intégrité des joints d'étanchéité.

e) Le traîneau s'est bien comporté lors des essais. Cependant, plusieurs défauts ont pu être remarqués: le principal étant son poids excessif, et d'autres plus légers se situant au niveau de l'étanchéité et des attaches à bascule. De l'eau a pénétré seulement dans un des compartiments d'extrémité et ce problème pourrait facilement être corrigé par un réglage des attaches à bascule. Les attaches ont été endommagées lors de la manutention du traîneau à bord du navire, mais cela pourrait probablement être évité en les encastrant; il serait toutefois préférable de les éliminer complètement en installant des trappes d'accès sur le dessus et le dessous du traîneau.

f) A partir des constatations faites au cours de ce projet, un plan de traîneau de seconde génération a été proposé; construit avec des matériaux allégés, il présenterait un volume et un poids réduits et n'aurait ni joint d'étanchéité "hémisphérique" ni attaches à bascule. Ce nouveau traîneau posséderait un compartiment unique muni de trappes d'accès situées sur le dessus et le dessous; de plus, il serait aussi large, mais beaucoup moins long et haut que le traîneau actuel. Ces modifications diminueraient un peu le volume du traîneau, cependant elles le rendraient plus maniable et moins coûteux.

Le rapport recommande que le contenu définitif de la trousse de survie soit arrêté avant de poursuivre l'étude du nouveau traîneau.

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	DESIGN	2
	2.1 Performance Requirements	2
	2.1.1 Volume and Weight of Contents	2
	2.1.2 Minimum Length and Width	3
	2.1.3 Watertightness and Floatability	3
	2.1.4 Strength and Resistance to the Environment	3
	2.1.5 East of Towing and Lifting	3
	2.1.6 Dropping from the Ship	5
	2.2 Materials	5
	2.3 Design	6
3.	CONSTRUCTION	9
4.	TESTING	11
	4.1 Hydrostatic Testing (in Ottawa and Montreal)	11
	4.2 Functional Testing (in the Arctic)	11
5.	DISCUSSION	20
	5.1 Design	20
	5.2 Testing	21
	5.3 Proposed Second Generation Design	22
6.	CONCLUSIONS	26
7.	RECOMMENDATIONS	28

APPENDIX 1 - Hydrostatic Test Programme

APPENDIX 2 - Functional Test Programme

APPENDIX 3 - Functional Test Report (Test Sheets)

1. INTRODUCTION

Lifesaving equipment which is required by regulations to be carried on board ships is either unsuitable for use in many conditions commonly found in the Arctic or, at best, requires modifications and should be supplemented by other equipment.

In many circumstances, when a ship must be abandoned in Arctic waters, abandonment will take place either directly onto ice or through water to 'safe ice', close to the ship, which would provide the survivors a place of 'safety' while awaiting rescue. There is presently no means to transport the necessary survival equipment from the ship to the ice, nor a means to move equipment across ice to a suitable location where camp can be made. Neither a lifeboat nor liferaft has sufficient capacity for both the crew and the quantity of Arctic lifesaving equipment which would be required.

Although work is still progressing to determine the minimum amount of equipment and food per person which is necessary while awaiting rescue, it is estimated to be about 0.15 m^3 and 12 kg if the rescue period or resupply period is assumed to be approximately seven to eight days. The equipment would include tents, sleeping bags, clothing, food, tools, stoves, etc. It is possible that some economies of volume and weight can be made, but these will not likely be substantial.

If this equipment is extended to a 30 person crew, 4.5 m^3 of equipment weighing 360 kg will be required. This is substantial and will be a transportation problem from the ship across water or ice which cannot be met by lifeboats and liferafts.

The most efficient means of handling this amount of equipment, and possibly injured persons, across open water to ice and subsequently across the ice is by sleds designed for the purpose. The sleds must be able to; (a) float while packed with equipment, (b) be dropped from a ship into water without damage, (c) be towed behind a lifeboat or liferaft, (d) hauled onto ice, and (e) towed across level and rough ice.

This report describes the process of designing, constructing and testing a prototype sled.

2. DESIGN

2.1 Performance Requirements

The first step towards designing the sled was to identify the performance requirements which had to be met by the prototype. Most of the requirements were already known from previous research. Other features to be incorporated into the design were determined through consultation with Coast Guard and National Defence experts.

In general, the survival sled had to be capable of carrying a predetermined quantity of survival equipment from a ship to safety on the ice and, subsequently, over the ice to an area of safety. The sled was to be lowered from the ship and towed through the ship's track by a lifeboat before being lifted onto the surrounding ice. The specific requirements which influenced the design are described below.

2.1.1 Volume and Weight of Contents

The contents of the sled was to include those items of survival equipment most likely to be required by the crew. The number of crew per sled was assumed to be ten. The sled design had to allow space for:

a) Clothing - Arctic winter gear including vacuum packed suits, gloves, boots, thermal underwear, etc. In addition to the full gear for ten persons, three contingency sets of Arctic clothing had to be provided. The space required would be about 0.36 m^3, and the the equipment would weight about 30 kg.

b) Sleeping Bags - Vacuum packed sleeping bags, designed for extreme cold, similar to those used by DND. The total space required would be about 0.15 m^3, weighing about 10 kg.

c) Food - The quantity of food was based on the need for 2,000 calories per person per day for seven days, i.e. a total of 14,000 calories. If dried food is used, no more than 0.10 m^3 of space would be required, weighing about 30 kg.

d) Underbody Insulation - Inflatable or expandable honeycomb, vacuum packed mattresses for each person. They would require about 0.2 m^3 of space, weighing about 10 kg.

e) Fuel - Naptha fuel for the cooking stoves, carried in cans or other containers. About 10 litres would be required, having a volume of about 0.01 m^3, weighing about 10 kg.

f) Cooking Appliances - Two stoves and other cooking and serving utensils such as pans, plates, knives and forks. The total volume would be about 0.03 m^3, weighing about 5 kg.

g) Set of Tools - An axe, snow shovel and two snow kits including saws and knives. The total volume would be about 0.02 m^3, weighing about 7 kg.

h) Two Person Tent - An emergency shelter for injured or hypothermic persons would require about 0.08 m^3, weighing about 5 kg.

These major items and several miscellaneous articles of survival equipment have been listed in Table 2.1. Adding a 10 percent contingency, the required volume of the sled totaled 1.10 m^3, weighing 125 kg. These numbers were subsequently used to determine the size of the sled.

2.1.2 Minimum Length and Width

The sled had to be capable of carrying an injured person in a prone position. Assuming a tall person would have a height of not more than 2.0 m (6'6"), the sled should have a minimum length on the carrying surface of 2.2 m and a minimum width of 0.75 m.

2.1.3 Watertightness and Floatability

The sled had to be watertight to ensure that no water could enter the storage compartments. The sled's interior had to be subdivided into separate watertight compartments. These compartments would provide protection of the cargo, lateral stiffness for the sled, and ensure floatation with one compartment holed.

2.1.4 Strength and Resistance to the Environment

The structure of the sled and its materials had to possess the following properties:

- be suitable for storage and operation at -40°C,
- be corrosion resistant in sea water and salt spray,
- have high impact toughness (similar to a lifeboat or liferaft canister),
- be fire resistant,
- have high tensile strength (similar to a lifeboat or liferaft canister),
- have low friction coefficient with ice and snow (at least on the runners).

2.1.5 Ease of Towing and Lifting

The sled had to be towed through the water and over the ice and snow. In the water the sled would be attached to a lifeboat or liferaft by a 'painter', requiring one or two towing points to be attached at each end. The ends had to be shaped to allow the sled to; (a) easily slide off small ice floes which may move into the wake of the lifeboat or raft and, (b) be pulled up onto large ice floes.

TABLE 2.1

STANDARD SURVIVAL PACKAGE FOR
10 PERSONS TO BE CONTAINED IN THE SLED

EQUIPMENT	QUANTITY	WEIGHT (kg)	VOLUME (m^3)
Insulated Suits	13		
Bootees and Heli Hansen Socks	13 pairs		
Thermal Underwear	13 sets	39	.36
Mitts	13 pairs		
Scarves	13		
Sleeping Bags	10	10	.15
Rations	10	30	.10
Underbody Insulation	10	10	.20
Naptha	10 litres	10	.01
First Aid Kit	1	2	.01
Stove (Optimus III)	2	3	.01
Axe (Hatchet)	1	3	.01
Snow Shovels	1	2	.01
Snow Kit (Saw, Knife)	2	2	.01
Matches	6 boxes	-	-
Candles	1 box	1	.01
Cooking Pots	2	1	.01
Cups (Melamine)	10	1	.01
Flashlight with Batteries	3	1	-
Heat Packs	3	1	.01
Toilet Tissue	6	1	.01
Survival Manual	1	1	-
Playing Cards	3 packs	-	-
Two Person Tent	1	5	.08
Sub Total		123	1.00
Contingency (10 percent)		12	0.10
Total		135	1.10

For ease of towing over the ice, the sled would have runners which were formed as an integral part of the sled's body. The runners should have a low friction coefficient, particularly for ice and snow. The towing connections would be used to manually tow the sled over the ice (perhaps aided by personnel pushing from behind).

For ease of lifting onto the ice, the sled had to be of minimum weight but had to be strengthened longitudinally. The technique which might be used would be to pull the sled onto the ice 'bow first', pivot the sled at about midpoint on the ice edge, then pull fully onto the ice.

2.1.6 Dropping From the Ship

In an emergency, the sled might be dropped from a ship's deck into the water. The construction should be suitable to withstand the loads imposed, and the watertightness should be suitable for the immersion which could result.

2.2 Materials

The choice of suitable materials for the sled structure was limited to reinforced plastics (RP) and aluminum/magnesium alloys. Both categories of materials are well known and widely used in the marine industry for manufacturing small boats and miscellaneous ship outfit and equipment.

After initial analysis of the properties of the materials, the aluminum and magnesium alloys were eliminated from further consideration. Although DND had developed a light magnesium alloy toboggan capable of being para-dropped, its size and functions were far from those that were required for the Arctic survival sled. The most important deficiency was its inability to float.

Reinforced plastics appear to be more useful than any non-ferrous alloy. The main advantages of the reinforced plastics were identified as follows:

- higher mechanical strength (with certain types of reinforcement components),
- better resistance to the marine environment,
- ease of forming desired shapes, and
- low specific gravity.

Table 2.2 supplements this list by giving some numerical comparisons.

Among the various combinations of reinforced plastics, epoxy resins filled with glass, graphite or synthetic fibres give the best shear strength and flexural properties. Fibreglass is the most common and moderately priced reinforcement, however, it is not of the highest strength. A large increase in strength can be achieved by using fibres developed in recent years made of graphite or Kevlar.

TABLE 2.2

PROPERTIES OF MAGNESIUM ALLOYS
AND REINFORCED PLASTICS

PROPERTY	MAGNESIUM ALLOYS	WOVEN GLASS REINFORCED EPOXIES	FILAMENT-WOUND REINFORCED EPOXIES
Specific Gravity	1.75 - 1.79	1.60 - 1.85	1.70 - 2.20
Tensile Strength (10^3 psi)	35 - 70	40 - 85	80 - 250
Impact Strength (Izool notched) ft lb/in notch	8 - 20	12 - 18	40 - 60

One of the latter, known under the trademark Kevlar, has gained acceptance in numerous commercial aerospace and marine applications. Kevlar possesses superior mechanical properties (especially impact strength) as well as good thermal stability. Even at cryogenic temperatures Kevlar shows essentially no embrittlement or degradation. In contrast to this, fibreglass becomes brittle in Arctic temperatures.

In view of these considerations and the relatively high cost of Kevlar, it was decided that the principal structure of the sled would be made of epoxy fibreglass. However, the areas to be subjected to ice loads would be reinforced with a single layer of Kevlar.

2.3 Design

Considering; (a) the specified performance requirements, (b) the suitability and cost of materials, and (c) the least costly manufacturing method, a sled design was produced and is shown in Figure 2.1.

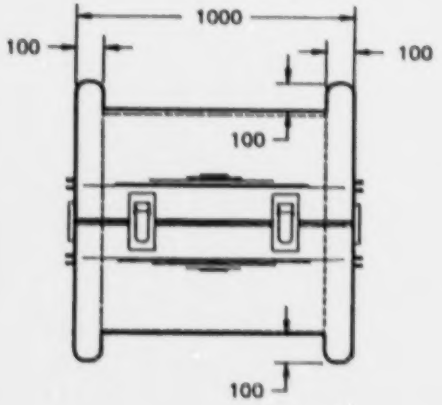
The concept assumes that the sled should have two identical top and bottom halves, allowing it to be launched in any position and then retrieved without concern over which was the top or bottom. The two halves would be joined together and made watertight by means of the 12 tension latches.

The inside space was divided by four watertight bulkheads forming five cargo compartments with a total volume of 1.5 m^3.

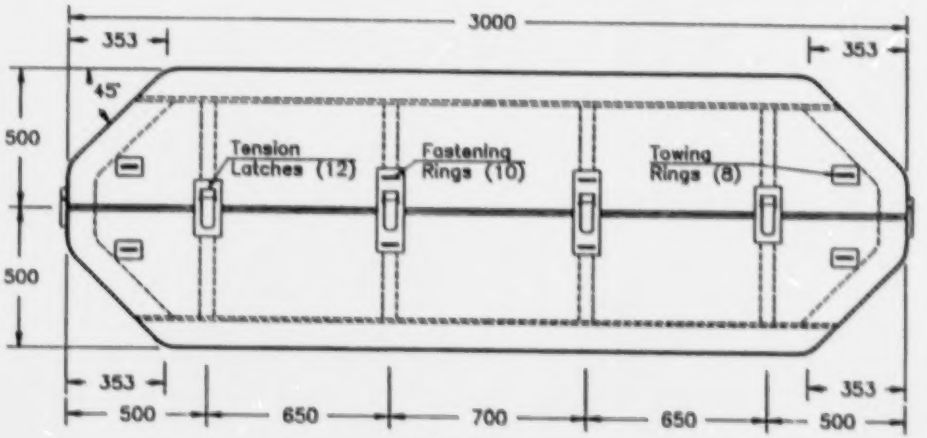
All details and dimensions have been determined in accordance with a proposed production method which assumed lamination of 100 mm thick polyurethane foam sheets for the side panels and 12.5 mm laminated plywood for the top and bottom.

FIGURE 2.1

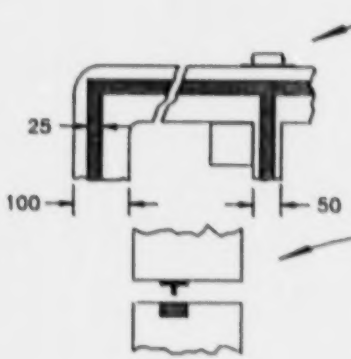
PROTOTYPE SLED DESIGN



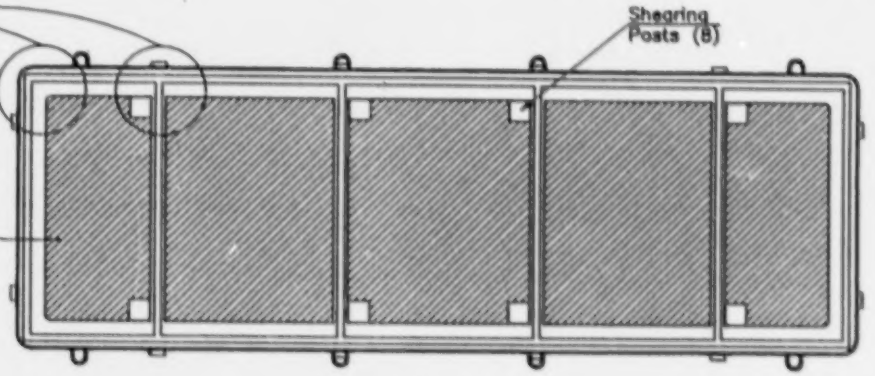
END ELEVATION



SIDE ELEVATION



DETAIL OF SEAL



SECTIONAL PLAN

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To protect both halves of the sled against movement while being launched into water, eight wooden shearing posts are provided in the corners of the cargo compartments.

The watertight seal between the two halves of the sled is comprised of a rubber gasket on one side and a compression bar attached to the other side. To ensure that the seal would be effective at Arctic temperatures the gasket was made of closed cell neoprene foam, which remains soft in a wide range of temperatures. Knowing the gasket setting stress and its dimensions, the required compression force and number of tension latches were calculated.

Eight towing and eight lashing rings are provided.

3. CONSTRUCTION

After several inquiries and discussions with potential manufacturers, it became clear that a production method based on the design and assembly of laminated sheets of polyurethane foam was the most appropriate for the construction of the sled prototype. The chief advantage of that method was price. The alternative method, which consisted of making a 'plug' which would in turn be used to make the 'mold' for producing the shell of the sled, was found to be almost four times more expensive and time consuming.

Fibron Industries Ltd. (Fibron) of Ottawa, a company which specializes in the construction of boats and industrial products in fibreglass, was selected as a contractor. They offered the lowest price and were able to deliver the prototype within the time frame required.

Stages of the prototypes construction are shown in Figure 3.1 and described below:

a) Side and end panels were prepared from sheets of 100 mm thick closed cell polyurethane foam of 48 kg/m^3 density. Foam of 50 mm in thickness was used for the internal bulkheads.

b) The base panels, top and bottom, were prepared from 12.5 mm plywood.

c) All panels were assembled and connected with laminated fibreglass joints. The corners were filled with epoxy putty in order to avoid sharp notches.

d) The foam panels were wrapped with two layers of fibreglass and saturated with epoxy resin.

e) The runners, sides and ends were reinforced with a layer of Kevlar, to provide higher impact resistance.

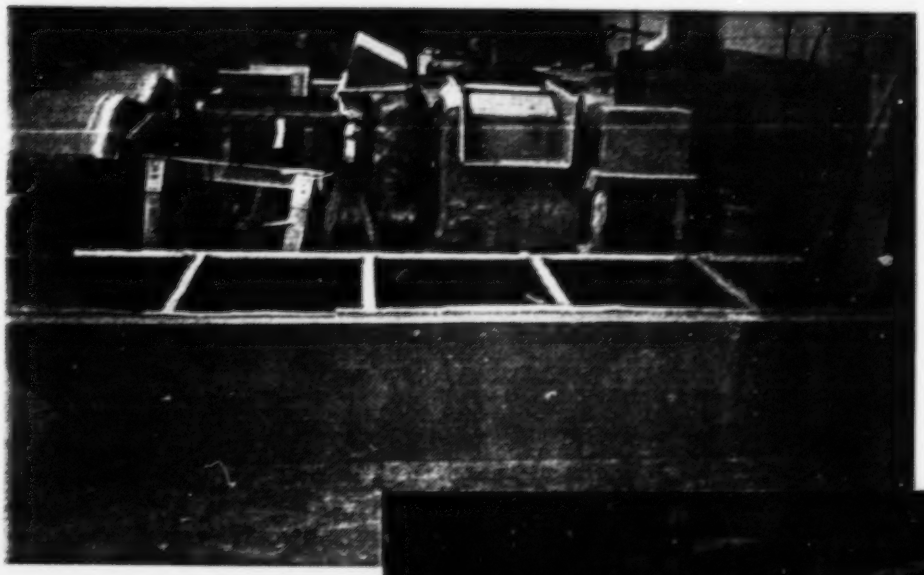
f) Wooden shearing posts coated with epoxy resin were fitted in one of the sled halves.

g) Tension latches and towing rings were fitted to aluminum plates previously inserted between the laminated layers. Latches of the required working strength, 2.9 kN, were found at Spae-Naur of Kitchener, Ontario.

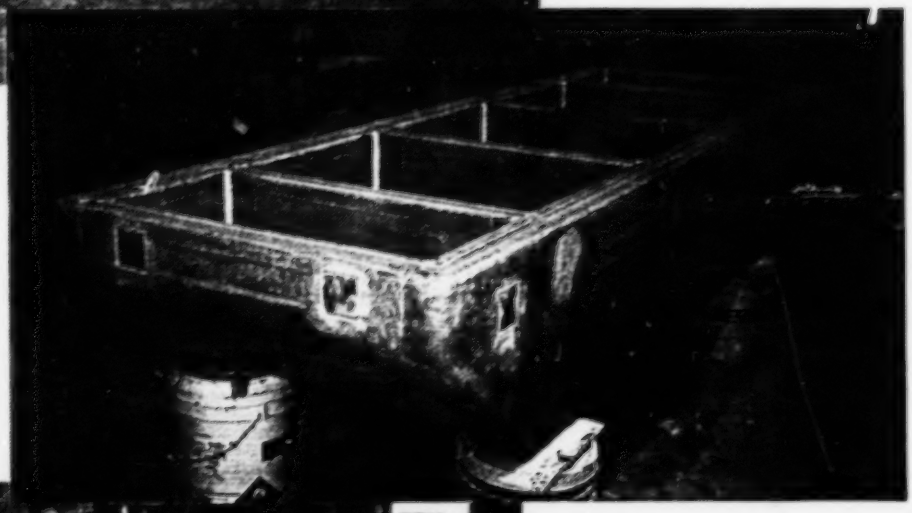
h) A watertight seal was fitted with one face consisting of a compression T-bar made of aluminum, while the other face was closed cell neoprene foam gasket suitable for temperatures to -40^{o}C. The gasket was recessed in a trough made in the sled body.

FIGURE 3.1

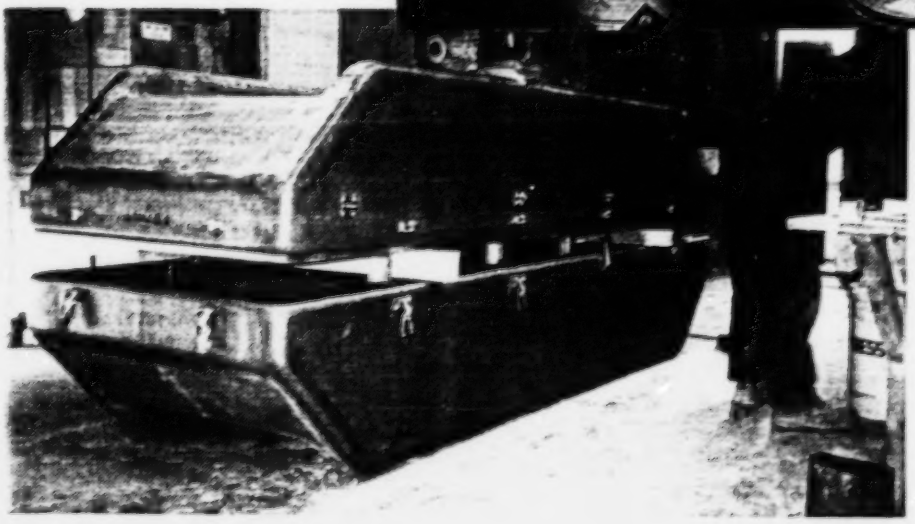
STAGES OF SLED CONSTRUCTION



FOAM PANEL
ASSEMBLY



ADVANCED STAGE
OF FIBREGLASSING



COMPLETED SLED
(BEFORE PAINTING)

4. TESTING

4.1 Hydrostatic Testing (in Ottawa and Montreal)

A set of hydrostatic tests were conducted in Ottawa and Montreal, as outlined in the test program attached as Appendix 1. The sled was taken to the Nepean Sailing Club and loaded with twelve 10 kg bags of ballast, representing its design capacity and volume. The ballast was distributed evenly throughout the sled with two bags in each compartment.

The sled was then launched into the yacht outfit well by means of a crane. The draft (20 cm) and period of roll (2.1 seconds) were measured.

All brackets and rings fixed to the sled for towing purposes were tested by using them for lifting the sled with the full design load. It was reasonable to assume that such applied load would be at least as high as the maximum expected load on those fixtures in a survival situation. By inducing sudden stops while the sled was lifted or lowered, the towing rings were tested under dynamic loads. No damage occurred to the fittings.

While being held by the crane in various positions, the sled was immersed in water to check watertightness of the seals and no leakage occurred.

The sled was transported from Ottawa to the Federal Marine Terminals Shed 42 in Montreal. The sled was inspected, the tension latches adjusted and the main rubber seal was hose tested. No leaks were found. Assisted by a harbour crane, the sealed sled was again dropped into water from a height of about nine meters, which could be considered as a maximum fall height in a real situation in the Arctic. The test was repeated four times, each time with the sled positioned in a different way relative to the water surface as described below;

- nose down,
- bottom down,
- side down, and
- slope down.

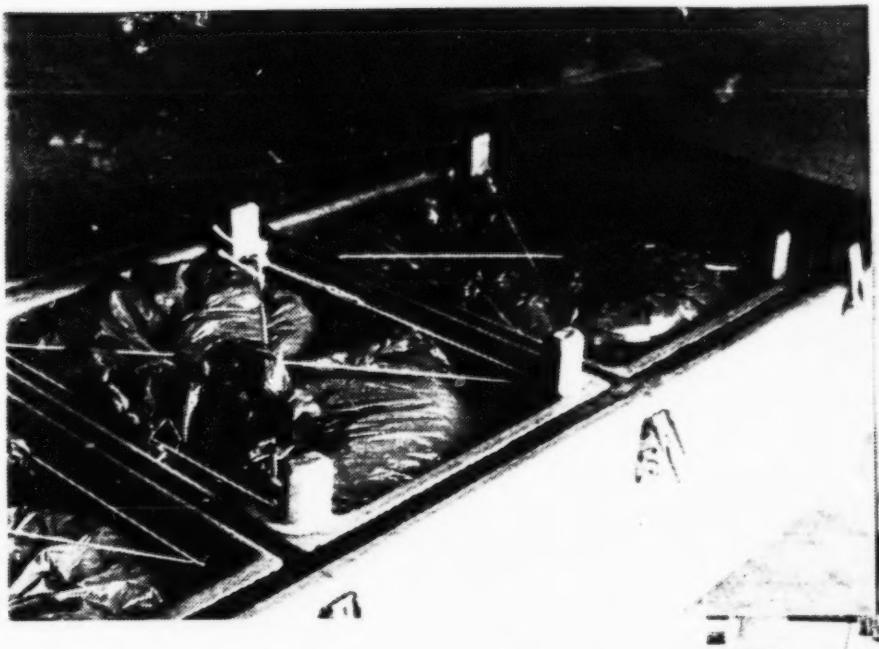
After each drop the sled was retrieved from the water and carefully examined. The sled suffered no damage to its structure but the tension latches were too weak to withstand impact of the fully loaded sled hitting the water surface. The reason for their failure lies in the weight of the sled being greater than initially estimated and, hence, greater inertia forces acting on the latches. As a result, the sled was returned to the manufacturer and the latches replaced with stronger ones.

4.2 Functional Testing (In The Arctic)

The sled was placed on board the CCGS JOHN A. MACDONALD in Halifax, bound for the Arctic. The planned tests were to identify deficiencies in performance of the sled as well as problems associated with its handling; (a) on board the ship, (b) in the water and, (c) on the ice. A copy of the proposed test program is attached as Appendix 2.

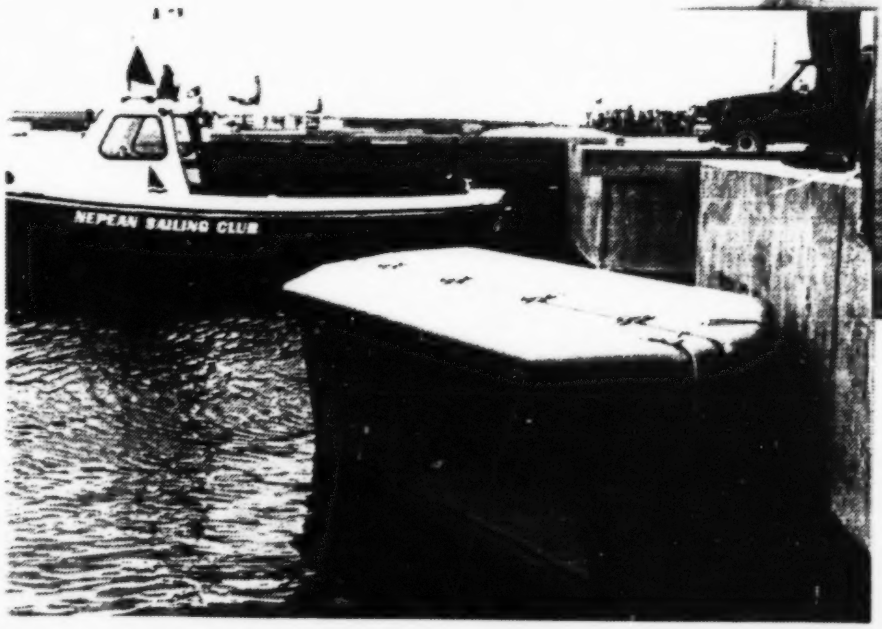
FIGURE 4.1

HYDROSTATIC TESTING IN OTTAWA



BALLAST STOWAGE
ARRANGEMENT

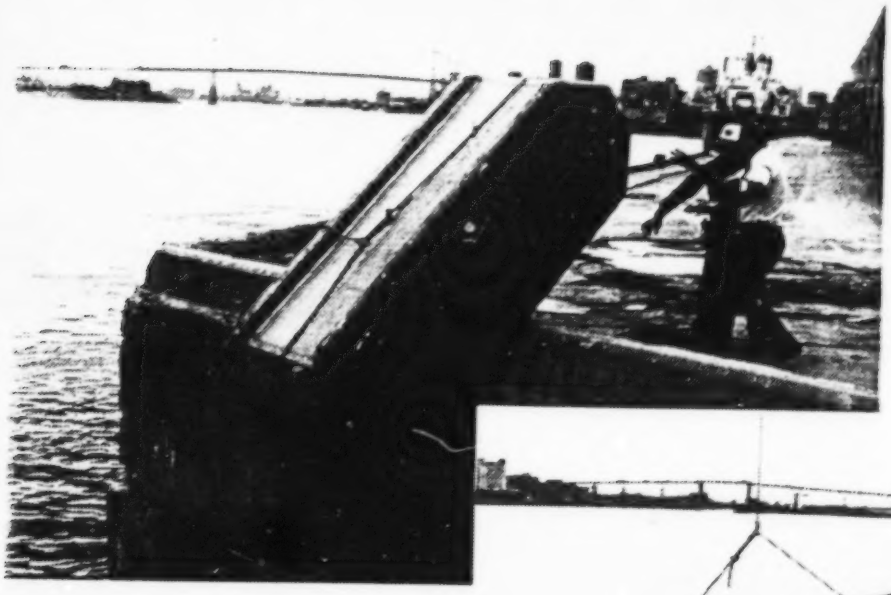
HYDROSTATIC TESTING
(NOSE DOWN)



HYDROSTATIC TESTING
(SIDE DOWN)

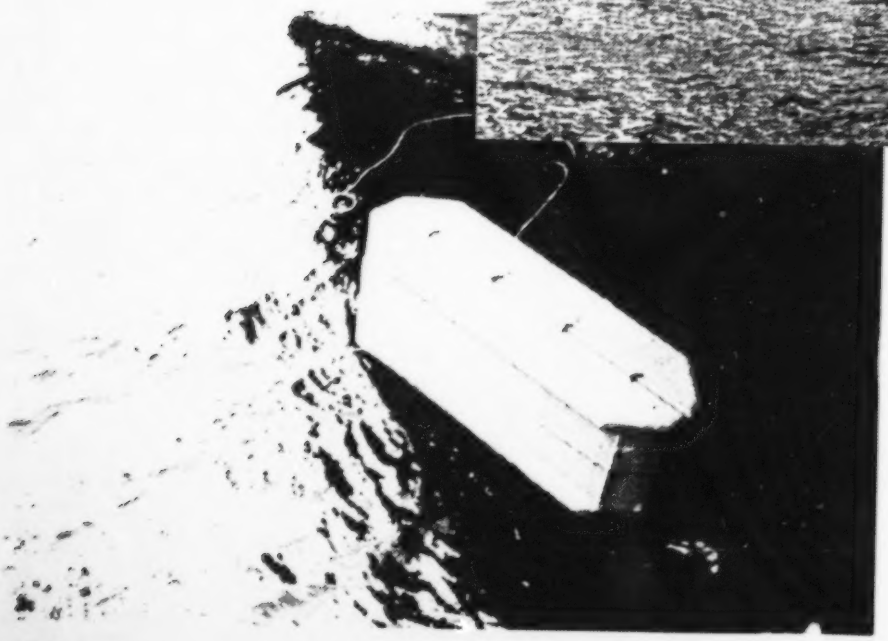
FIGURE 4.2

DROP TESTING IN MONTREAL



RELEASING FROM
THE QUAY SIDE

DROP TEST ON
THE BOTTOM



DROP TEST ON
THE SIDE

The sled was recognized to be excessively heavy and, because of that, it was not loaded to its design capacity. Rather, a portion of its own weight was considered equivalent to the weight of the survival equipment.

The tests took place on July 19, 1988, off Resolute Bay. The ship was staticnary in 9 to 10/tenths ice cover comprising a mixture of relatively flat ice with ridged and rubbled areas with scme snow cover and refrozen melt pools. These conditions are illustrated by the photograph below.

FIGURE 4.3

ICE CONDITIONS OFF RESOLUTE BAY
July 19, 1988

The air temperature was about 5°C with wind speeds varying from 0 to 25 knots.

The tests which were conducted included:

- moving the sled into position on the deck,
- launching the sled into the water,
- towing the sled through the water and pack ice,
- pulling the sled into an ice floe,
- towing the sled over ice and snow,
- retrieving the sled from the water, and
- drop tests.

These tests were all completed successfully and a report of each test is attached as Appendix 3. The most important findings are reviewed below and several supporting photographs are shown in Figure 4.4.

a) Physically lifting the sled was difficult due to a lack of handholds and to its heavy weight. **At about 340 kg, the sled is too heavy for ease of handling.**

b) Six crew members volunteered for the duties involved in towing the sled through the water and over the ice. They donned their immersion suits, taking about five minutes to complete the exercise. The undersoles of the suit were covered with a reinforcing pad designed, presumably, for abrasion resistance rather than for traction on an ice or snow surface. **Nevertheless, traction was quite good.**

c) The sled was picked up by the crane using a simple rope sling, swung over the side and lowered gently to the water. No difficulty was experienced and the operation took about three minutes. Marshalling of the sled from a self propelled work barge was quickly completed.

d) The work barge accelerated through the water (free of any ice) to a speed of about six or eight knots, easily towing the sled. The sled generally took up a crabbed attitude to the work barge, i.e. leading with one of the corners. A small bow wave was created which made the forward draft about 0.5 m. At slower speeds the sled's draft was in the range of 200 mm to 300 mm. **Except for the crabbing attitude of the sled there were no difficulties in open water towing.**

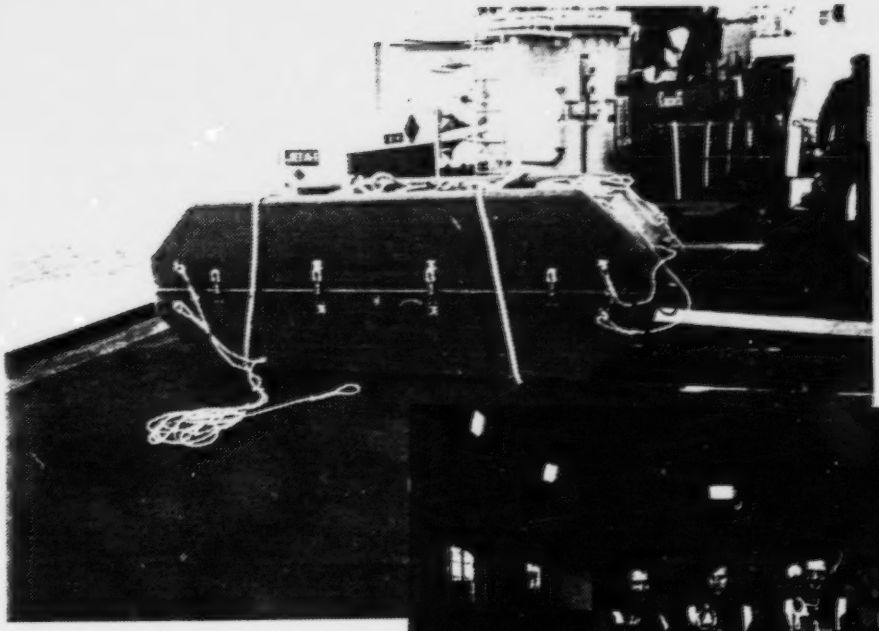
e) Manoeuvring the sled was not difficult although it swung wider than the work barge at times.

f) **When the sled encountered broken ice pieces it reacted by bouncing over or off the ice. Small pieces had little effect, larger pieces deflected the sled upwards and to the side. Very large pieces caused the sled to ride up over the ice, at times lifting the sled completely out of the water.** On one occasion, the sled contacted a very large ice piece with only one side (runner). The effect was to tip the sled over by 180°.

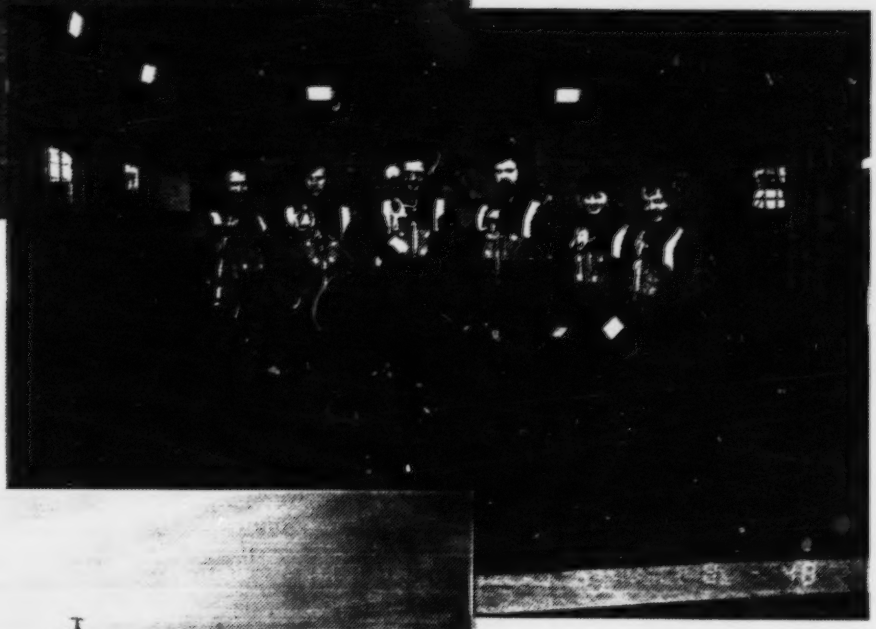
g) A second bridle towing arrangement was tried, i.e. one bridle attached to the lower port and starboard towing eyes, linked to the work barge by one rope. The result was to create a more stable motion, eliminating the crabbing attitude. In addition, the sled turned more tightly with the barge rather than swinging wide. **Overall, a single tow rope is a much preferred towing arrangement.**

FIGURE 4.4

PREPARATIONS FOR THE FUNCTIONAL TEST PROGRAM



SLED READY FOR LAUNCHING

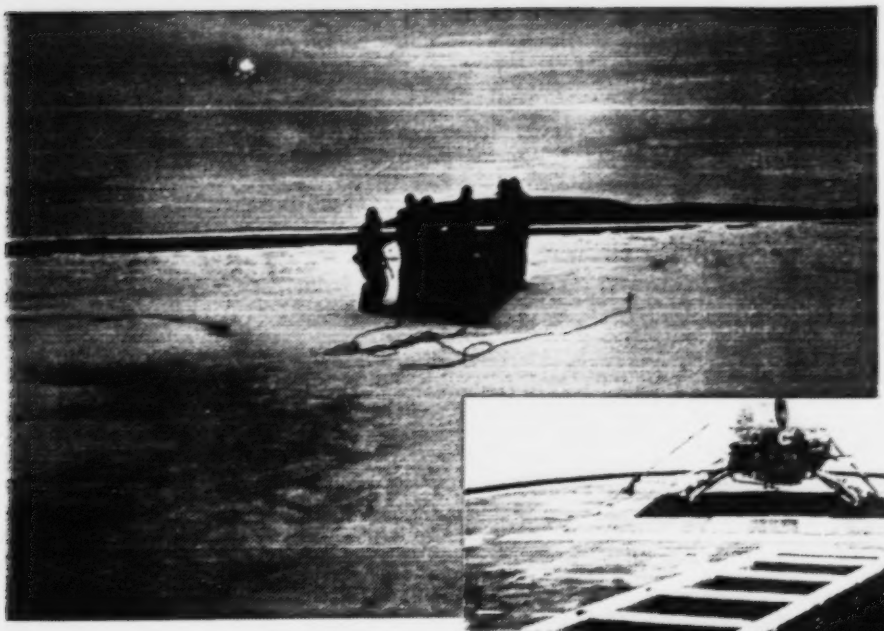


VOLUNTEER GROUP IN IMMERSION SUITS

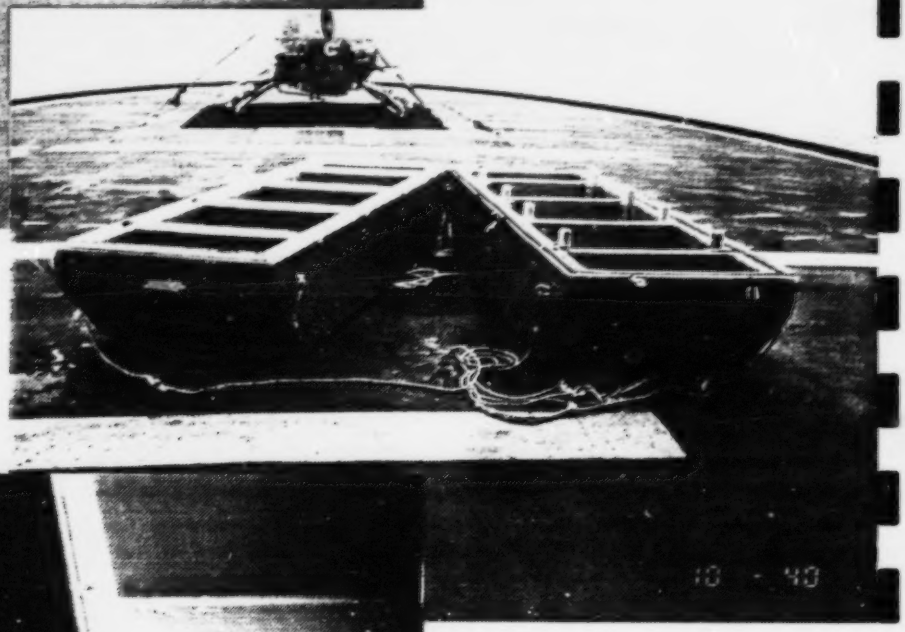
SLED BEING LAUNCHED FROM THE SHIP

FIGURE 4.4 (CONT'D)

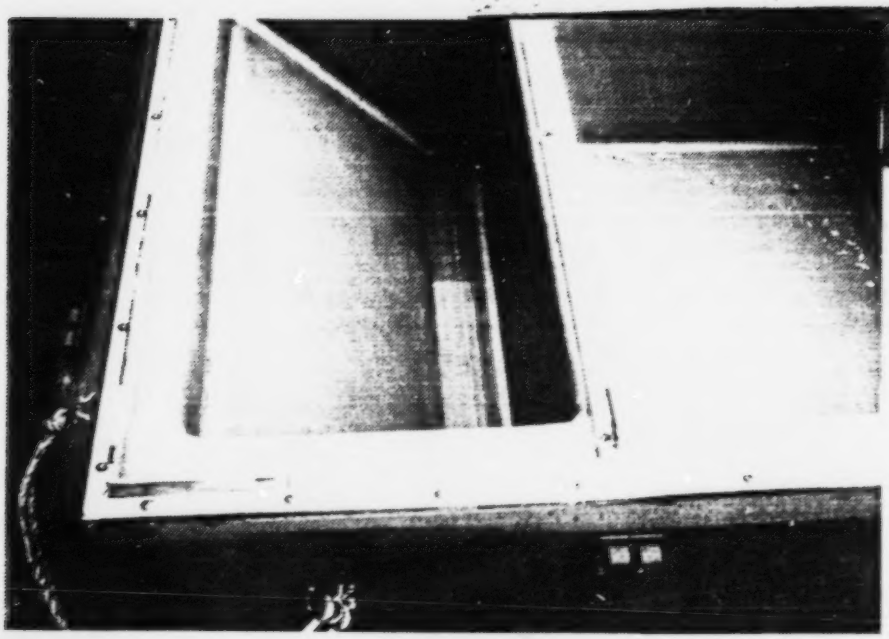
ASPECTS OF THE FUNCTIONAL
TEST PROGRAM



THE SLED ON A
LARGE ICE FLOE



THE SLED DURING THE
AFTER TEST INSPECTION



LEAKAGE IN THE
FORWARD COMPARTMENT

h) **The sled was easily pulled onto a large floe.** First a single person attempted to lift/pull the sled onto the ice, and almost succeeded - the sled was 50 percent out of the water before it became too difficult and was allowed to slide back. A second person joined the first and easily pulled the sled onto the ice.

i) **The traction offered by the undersoles of the immersion suit was quite good, resulting in very little slipping underfoot - even while pulling the sled out of the water.**

j) **The sled could be pulled by two men with little difficulty over flat ice with hard snow cover, even over slightly rough or undulating terrain.** The sled runners moved easily over the hard packed snow with no visible adhesion. Only when the sled was pulled through a small melt pool, wetting the runners, was an additional drag noticed.

k) **The sled could easily be pulled and pushed over rough ice conditions.** The team was organised with four at the front pulling (two each side) and two behind pushing. In this way the sled could be moved over ice ridges and rubble, which was about 1.50 m in height with continuous changes in profile. Some difficulty was found when moving the sled up a long slope - at one point becoming stopped with all volunteers straining to move it forwards. With considerable effort it moved forward up the slope and over the crest. This problem could be overcome by developing an appropriate sled handling technique.

l) The sled was towed back to the ship and lifted out of the water (end first) and on to the helicopter deck. The sled was opened quite easily, although there was some sticking between the upper and lower half. No damage had occurred to the latches and each could be opened with bare hands - and with some difficulty with gloves on. **Opening the latches with immersion suit gloves (one piece) was very difficult - the opening lever is too small and snuggly fits into the sled's side. A latch should be found which allows the use of a gloved hand, or the latches should be dispensed with in the final design.**

m) Leakage had occurred only in the end compartment which had been facing forward during towing. This compartment is triangular in shape with a peak at the bottom. This peak had about 50 mm of water in it. All other compartments were completely dry.

n) **There was no visible damage to the seals, nor to the sealing bars.** Presumably there is some uneveness in the seal material or the bearing bar or the latches at the end were not sufficiently tight. The sled was not subjected to a water head of pressure, only to a bow wave of a few centimeters. This implies a very loose mating surface between the bearing bar.

c) The sled was dropped into the water from a height of about 10 m in three altitudes, i.e. bottom down, side down and end down. On inspection after the drop tests it was found that no damage had occurred to the structure, latches or seals and no additional leakage was found. The same amount of water remained in the end compartment and all other compartments were completely dry.

5. DISCUSSION

5.1 Design

The shape and dimensions of the sled are guided primarily by the requirements that it; (a) be of sufficient length to carry an injured person and, (b) have sufficient volume to carry a predetermined quantity of survival material plus some margin for additional equipment which is yet to be identified. Additionally, the sled had to be watertight, floatable and structurally strong.

The design process was also influenced by the need to produce only one prototype. Whereas a production quality design would have special features to permit mass production, the prototype was deliberately designed to be inexpensively constructed as a single unit. After reviewing two offers from fibreglass boat builders the offer from Fibron, and their proposed mode of construction, was accepted.

The design/construction process has lead to the design shown in Figure 2.1 and in the various photographs. The sled produced is much stronger and heavier than expected, due mainly to the absorption of epoxy resin by the high density foam panels. In addition, there was some leakage (small amount) and the latches are susceptible to damage.

Another concern is the ability of survivors to access the survival equipment in the sled where there is no walkable ice in the vicinity and the sled is floating alongside the lifeboat. One option is to install watertight openings in the top and bottom, located and designed so as to be readily reached by survivors in the lifeboat. If designed with openings only on the top, and if it was immersed top down in water, it may not be possible to over turn the sled.

This arrangement of openings has the added advantage of permitting the whole sled to be built in one piece. This would eliminate the hemispherical seal, which requires a very stiff structure, and will permit a reduction in the thickness of the side structure and, hence, result in a reduction of weight.

It has been shown that the sled can be pulled easily from water onto ice and can be handled easily, even on rough ice. However, some improvements would be worthwhile. Increasing the flare of both ends would make retrieving the sled from the water easier. Handling of the sled on ice or on the ship would also be easier if a set of handholds were fitted to the side walls. In the present design, all of the tension latches were fitted directly to the flush side walls making them prone to damage from ice floes or other mechanical obstacles. In an improved design, if tension latches are installed, regardless of their location and function, they should be well protected by installing them in recesses of sufficient depth. The dimensions of the latches should be such that they could be easily handled by people wearing gloves or immersion suits, and all metal parts should be plasticised to protect against accidentally freezing of bare hands at low temperatures.

The towing rings appear to be adequate, but rings of greater diameter would be easier to use and would be less prone to damage. Recessing the rings should be considered in a modified design or towing rings and hand holds could be combined.

The chief weakness of the present design appears to be its excessive weight. It was expected that the weight of the empty sled should be about the same as the weight of its load, i.e. a total of about 240 kg. This estimate was confirmed by weight calculations based on dimensions from the design drawing and the following construction materials data:

- PU foam density 48 kg/m^3
- plywood density 900 kg/m^3
- fibreglass laminate density 2,000 kg/m^3
- fibreglass laminate thickness 3 mm
- weight of steel fittings 5 kg

The weight calculated was 252 kg. However, the final product reached 340 kg. This means that the thickness of fibreglass laminate, especially in those areas reinforced with Kevlar, considerably exceeded the design value of 3 mm. In addition, substantial amounts of epoxy resin and putty, more than anticipated, were used to fill in the corners of the structure.

The reason for the abundant use of resin was apparently to provide a higher degree of strength and stiffness to the construction. That was achieved to a greater degree than expected. After several drop tests, towing through ice infested waters, and rough handling during transportation and on the ship, the sled suffered no damage to its structure. Therefore, the production version of the sled should be made lighter by using fewer layers of fibreglass, applying Kevlar mats by substituting it for the last layer of fibreglass rather than as an additional layer, reducing the thickness of foam panels to 75 mm and, finally, eliminating the top and bottom plywood plates and replacing them with laminate walls.

Changing to a 'mold' type of manufacturing method will likely reduce the weight of the sled even further since reinforcement of all corners with putty and resin will be avoided and replaced with rounded laminate layers of uniform thickness.

5.2 Testing

The use of drop tests, various attempts of using towing and lashing rings for lifting the empty or loaded sled, fast towing of the sled through ice floes, etc., seemed to be appropriate and sufficient to prove without any doubt the strength of the sled.

The functional tests were also successful. However, the functional tests covered the factors and situations relevant to only one survival scenario in which survivors abandon the ship and evacuate to nearby fast ice in favorable atmospheric conditions, i.e. temperature around freezing and in day light. For safety and economic reasons it is not possible to conduct tests in all as survival scenarios. Instead, the tests already conducted should serve to indicate how useful a sled might be in more severe conditions.

5.3 Proposed Second Generation Design

Considering the results of the design, construction and testing program for the prototype sled, it is important to consider how the design would be influenced by the experience gained. Although the test program considered only one environmental scenario, the lessons learned are sufficient to provide guidance in assessing the usefulness of the concept.

Before looking at adjustments to the design, the initial requirements should be assessed. The basic requirements are:

a) that the sled should carry at least 1.10 m^3 of materials in a watertight environment,

b) that an injured person can be carried prone on top of the sled,

c) that the sled is sufficiently strong to withstand dropping off the ship into water and colliding with ice pieces when being towed.

It is these requirements which govern the size and strength of the unit. The existing design complies with all requirements and includes margins for increasing requirements at a subsequent date. However, if the minimum size unit is to be provided, i.e. to hold the defined survival pack for ten persons and to carry a person of no more than 1.8 m in height, then the size can be considerably reduced. The survival pack described in Section 2.1.1 may also be adjusted to reflect the likelihood that supplies of food and special tents can be air dropped to ship evacuees if rescue will not be possible for an extended time (such as seven or eight days). A modified survival pack is shown in Table 5.1. The resulting weight is 94 kg with a volume of 0.79 m^3. This eliminates the additional sets of clothing and the two person tent.

If no margins are allowed on these basic requirements the sled could be reduced in size, as shown on Figure 5.1 This figure shows the original and revised sleds, illustrating the dramatic difference in size. In addition to the volume difference there are several other design refinements which could be made. These are:

a) The hemispherical seal can be removed along with all latches and related seal hardware. Since the seal leaked a small amount during the functional tests, this measure will eliminate a problem. The difficulty in opening and closing the seals and in separating the two halves of the sled will also be eliminated.

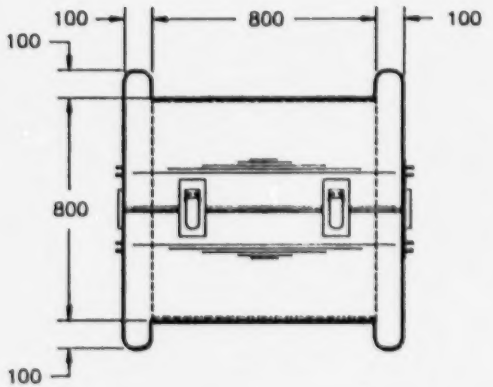
b) The internal subdividing bulkheads may be removed, making one cargo space. The high strength of the sled structure should eliminate the need for this subdivision. Even if holed, the sled will float.

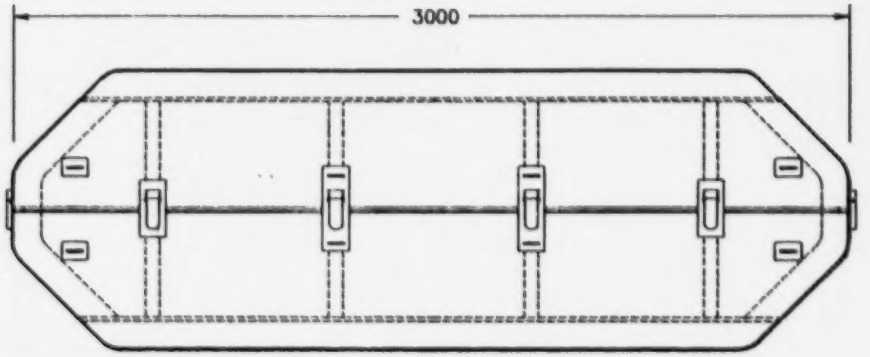
TABLE 5.1

STANDARD SURVIVAL PACKAGE FOR
10 PERSONS TO BE CONTAINED IN THE SLED

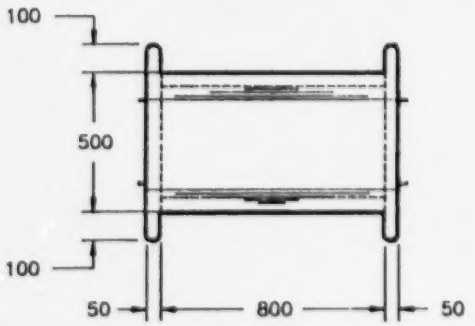
EQUIPMENT	QUANTITY	WEIGHT (kg)	VOLUME (m^3)
Insulated Suits	10		
Bootees and Heli Hansen Socks	10 pairs		
Thermal Underwear	10 sets	30	.28
Mitts	10 pairs		
Scarves	10		
Sleeping Bags	10	10	.15
Rations	10	15	.05
Underbody Insulation	10	10	.20
Naptha	10 litres	10	.01
First Aid Kit	1	2	.01
Stove (Optimus III)	2	3	.01
Axe (Hatchet)	1	3	.01
Snow Shovels	1	2	.01
Snow Kit (Saw, Knife)	2	2	.01
Matches	6 boxes	-	-
Candles	1 box	1	.01
Cooking Pots	2	1	.01
Cups (Melamire)	10	1	.01
Flashlight with Batteries	3	1	-
Heat Packs	3	1	.01
Toilet Tissue	6	1	.01
Survival Manual	1	1	-
Playing Cards	3 packs	-	-
TOTAL		94	0.79

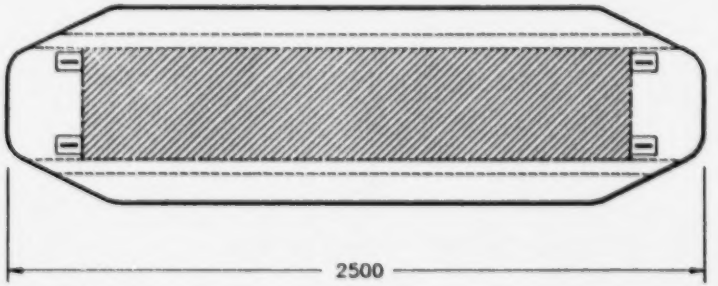
FIGURE 5.1
FIRST & SECOND GENERATION SLED DESIGN





FIRST GENERATION





SECOND GENERATION

c) The end compartments will be filled with foam to ensure floatation if the sled is holed.

d) The side walls and top and bottom have been replaced with 50 mm thick foam with one layer of fibreglass and one of Kevlar.

e) The width of the sled has been maintained as the original but the height has been reduced to improve stability in the water and on the ice.

f) A watertight access hatch is located on the top and bottom surfaces, comprising a recessed plate cover with neoprene seal tightened by butterfly nuts coated with a plastic material. Since the materials inside the sled will be in plastic bags impervious to water, any minor leakage will be inconsequential.

g) A plastic coated lifting bar will be attached to each end of the sled.

These features reflect the important lessons learned during the design, construction and testing of the original sled. Although some compromises have been required in the make-up of the survival pack these can be compensated for by assuming the use of air drops.

6. CONCLUSIONS

The design, construction and testing of an Arctic Survival Sled has been successfully carried out. The work has resulted in an increase in our understanding of the problems involved in the survival of ships' personnel in the Arctic. Several conclusions can be extracted from each aspect of the program are described below.

1. Design

a) The importance of the sled's weight requires the survival pack contents to be carefully specified with a full understanding of the weight and volume of each item.

b) For the sled to be of least weight and size, the volume of the survival pack should be kept to a minimum relying on the air-drop of supplies for extended survival periods.

c) The sled should have no hemispherical seal and associated latches to limit the potential for leakage and eliminate the use of latches which can be difficult to operate and sensitive to damage.

d) All metal attachments should be coated in a plastic material to prevent injury in cold temperatures to bare hands.

e) The sled is too strong, sustaining no structural damage despite very rough treatment. The thickness of the side walls can be reduced by 50 percent to no more than 50 mm and the top and bottom panels can be the same as the side walls. The high density foam panels can be sheathed in one layer of fibreglass and one of Kevlar. The nose compartment at each end can be filled with foam to absorb any impact damage.

f) The production version should be constructed using a 'mold/ plug' system to facilitate cost efficient manufacture. This will require a new design which has not been developed within the scope of this project.

2. Construction

a) The method of construction, which was selected for ease of constructing a one-off prototype, resulted in the sled being heavier than expected. The epoxy was more easily absorbed by the foam and consequently weighed more.

b) The selection of 100 mm thick side panels wrapped with two layers of fibreglass and one of Kevlar (on the outer surface) resulted in an extremely strong structure.

c) The selection of 12.5 mm plywood sheathed in fibreglass and Kevlar is too strong and heavy, particularly consicering the internal subdivision of the sled.

3. Testing

a) All tests were carried out successfully in Ottawa (at Nepean Sailing Club), in Montreal (at the Fednav Terminal), and off Resolute Bay, NWT (on board the JOHN A. MACDONALD).

b) The sled was found to be:

- watertight, except for a minor leak during the trials off Resolute Bay,
- difficult to lift or move around the deck or on land due to its weight and size,
- easily marshalled alongside the ship using a small work barge,
- easy to tow through water or a mix of ice and water, limited only by the ability of the towing,
- easy to pull onto a large ice floe using only two persons,
- easy to pull over relatively flat ice and snow using only two persons,
- easy to pull/push over rough and rubbled ice using six persons, four pulling and two pushing,
- difficult to open with gloved hands due to the latches being quite tight against the side of the sled, and
- difficult to separate into two halves due to the seal sticking and the sled's weight.

4. Second Generation Sled

a) The sled should be designed to carry either 1.10 m^3 of equipment (as required for the prototype sled) or 0.79 m^3 (as required for a slightly reduced survival pack).

b) The sled width should be maintained and the length and depth reduced to provide only the required volume (i.e. without undefined volume margins). A lower depth with the same width will make the sled more stable.

c) The sled structure should be changed such that the side walls, top and bottom are made of 50 mm thick high density foam protected against absorption of epoxy. Each surface should have one layer of epoxy coated fibreglass mat with one layer of Kevlar on the outside only.

d) Access should be from two watertight covers on the top and bottom. These covers should be attached by plastic coated butterfly nuts easily tightened and opened by hand. This measure will eliminate the hemispherical seal and associated latches of the prototype and will permit access from a life-boat or liferaft floating along side.

e) A plastic coated lifting bar should be attached across each end of the sled with towing shackles attached on each side.

7. RECOMMENDATIONS

This project has resulted in a number of recommendations for future action. These are outlined below.

a) The absolute need for an Arctic survival sled should be reviewed and confirmed before any further development work takes place. This review should consider a range of ship types and Arctic seasons and should focus on the circumstances surrounding a likely ship evacuation.

b) The contents of an Arctic survival pack should be finalised and specified. Methods of packing should be investigated and variations should be reviewed on the basis of ship type and operating season and location.

c) After the contents of an Arctic survival pack have been established, the type of container which is best suited to a range of ship types should be developed first in concept and later in detail.

d) At each stage of development of the survival pack and sled, the recommendations should be reviewed by the marine industry and by the Canadian Coast Guard, Fleet Systems.

- APPENDIX 1 -

HYDROSTATIC TEST PROGRAMME

OUTLINE PROGRAMME FOR TESTING THE PROTOTYPE OF ARCTIC SURVIVAL SLED

According to the work plan, the sled will be subject to several tests in order to ensure that the design requirements are met. The tests described below will be managed by an engineer of Melville Shipping. If any of the tests fail, the next test will not be started until the cause of failure is rectified. If this requires changes to the time frame of the programme, all participants and witnesses of the tests would be notified and new dates set up.

1. Wednesday, May 18, 1988 (or before)

   Initial Test - At the completion of manufacturing the sled will be sealed and the main rubber seal will be hose tested at the premises of Fibron Industries in Ottawa. In case of any leaks the tension latches will be readjusted. All fittings will be examined and preliminary tested by applying static loads by available means.

2. Thursday, May 19, 1988

   Floatation Test - The sled will be taken to the Nepean Sailing Club, Stillwater Drive, Nepean, and loaded with six 20 kg bags of ballast representing its design weight and volume. The ballast will be distributed evenly throughout the sled, one bag in each of the compartments, to simulate the survival equipment.

   The sled will then be launched into the yacht outfit well by means of a crane. The trim and freeboard will be measured and stability determined by measuring the period of roll and deriving the GM.

   All brackets and rings fixed to the sled for towing purposes will be tested by using them for lifting the sled with the full design load. It is reasonable to assume that such applied load will be at least as high as the maximum expected load on these fixtures in a survival situation. By inducing sudden stops while the sled is lifted or lowered, the towing rings will also be tested under dynamic loads.

   Then the sled, held by the crane in various positions, will be immersed into water to check watertightness of the seals.

3. Thursday, May 26, 1988

   Drop Test - The sled will be trucked from Ottawa to Montreal to the Federal Marine Terminals, Shed 42. Using a harbour crane and a quick release hook the sled will be dropped into water from a height of about five meters, which could be considered as a

maximum fall height in a real situation in the Arctic. The test will be repeated three times, each time with the sled positioned in a different way relative to the water surface. The following positions are proposed:

- nose down,
- bottom down,
- side down, and
- slope down.

After each drop the sled will be retrieved from water and carefully examined for any structural damages or leakages.

- APPENDIX 2 -

FUNCTIONAL TEST PROGRAMME

- APPENDIX 3 -

FUNCTIONAL TEST REPORT

- Test Sheets -

FUNCTIONAL TESTS OF THE ARCTIC SURVIVAL SLED

on

CCGS JOHN A. MacDONALD

July 1988

by

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FUNCTIONAL TESTS OF THE ARCTIC SURVIVAL SLED

1. BACKGROUND

Lifesaving equipment which is required by regulations to be carried on board ships is either unsuitable for use in many conditions commonly found in the Arctic or, at best, requires to be modified and supplemented by other equipment.

In many circumstances, when a ship must be abandoned in Arctic waters, abandonment will take place either directly onto ice or when there is "safe ice" close to the ship which will provide the survivors a place of "safety" while awaiting rescue. At present there are no means provided which will permit the necessary survival equipment to be transported from the ship to the ice, nor a means to move equipment across ice to a suitable location where camp can be made. If either a lifeboat or liferaft is to be used to evacuate a ship, neither have sufficient capacity for both crew and the quantity of Arctic lifesaving equipment which will be required.

Although work is still progressing to determine the minimum amount of equipment and food per man necessary to await rescue, it is estimated on the basis of present work to be about 0.15 m^3 and 12 kg per man, if the rescue period or resupply period is assumed to be about seven to eight days. This equipment will include tents, sleeping bags, food, tools, stoves, etc. It is possible that some economies of volume and weight can be made, but these economies will not be substantial.

If this equipment is extended to a 30 person crew, 4.5 m^3 of equipment weighing 360 kg will be required to be removed from a ship. This is substantial and clearly represents a transportation problem from the ship across water or ice, which cannot be met by lifeboats and liferafts.

The most efficient means of handling this amount of equipment and possibly injured persons across open water to ice and across ice is by sleds designed for the purpose. The sleds must be able to float while packed with equipment, be dropped from a ship into water without damage, towed behind a lifeboat or liferaft, hauled onto ice, and towed across level and rough ice.

As far as is known, there are no sleds which meet these requirements. The Department of National Defence uses a sled which is packed with survival equipment and can be air dropped. This sled lacks the volumetric capacity that will be required for ships' lifesaving equipment and does not float.

2. DESIGN AND CONSTRUCTION

The sled has been designed and constructed taking into consideration the following points:

- capacity of the sled should be approximately 1.5 m^3 totaling 120 kg,
- length not less than two metres and suitable for the transportation, over level ice, of a person lying down,
- to be watertight,
- construction is to be from engineering materials suitable for use in temperatures of -40°C,
- construction material to be corrosion resistant in seawater,
- construction material to be fire resistant,
- should be able to be constructed inexpensively,
- should be able to be dropped from a ship into water without damage or loss of watertightness,
- should be able to be towed across a variety of ice terrains,
- should be capable of being towed behind a lifeboat or liferaft,
- should be capable of being lifted or hauled from water onto an ice floe,
- should be as compact as possible and designed to be easily stowed on board a ship.

The prototype of the sled has been built of fitreglass reinforced with the ultra strong fibre called KEVLAR.

3. TESTS

The initial drop tests of the sled into water have been carried out in Montreal. They proved the high structural strength of the sled. The sled has been placed on board the CCGS JOHN A. MACDONALD to be tested in Arctic conditions. It is expected that such tests will identify deficiencies in performance of the sled as well as problems associated with its handling on board the ship, in the water and on the ice. This will help to modify the prototype and produce an efficient and essential item of the Arctic survival equipment.

One of the deficiencies which has already been recognized is the excessive weight of the sled. This has been caused by the selection of a unique manufacturing method most suitable for a single, low cost, prototype. Serial production of the survival sled would be based upon a completely different methodology which would result in substantially lower weight.

Because of that, the sled will not be loaded to its design capacity, rather, a portion of its own weight will be considered as an equivalent to the weight of the survival equipment enclosed in the available volume of the sled.

The tests to be performed on the CCGS JOHN A. MACDONALD will consist of the following activities.

1. The sled will be taken from storage and transported to a suitable place on the deck. By means of a crane or a landing boom the sled will be launched overboard into water and secured at the ship side. Observations recorded during this operation should include:

   - problems with handling of the sled on board the vessel,
   - number of persons involved,
   - time required for launching the sled,
   - safety considerations,
   - suggestions on the best permanent location of the sled on board the vessel and launching arrangement, etc.

2. Either a lifeboat or rescue boat will be launched and the sled will be towed through the surrounding water and ice floes to a nearby ice floe of sufficient size to allow people to disembark from the boat and try to pull the sled a certain distance over the ice. It will be useful to tow the sled through both open and closed pack ice as far it is possible and safe. Observations should focus on:

   - handling of the sled while towing,
   - ease of manoeuvring,
   - stability of the sled,
   - resistance to collisions with ice,
   - efficiency of the closing arrangement, etc.

3. After disembarking, the lifeboat crew will try to pull the sled onto the ice. First attempts will be made with as few persons as possible; if not successful, more persons will be used. Observations should include:

   - main reasons for difficulties in pulling the sled onto the ice,
   - location of the sled towing rings,
   - height of the ice above sea level,
   - time required to retrieve the sled,
   - number of persons involved,
   - needs for supporting equipment, etc.

4. While on the ice, the sled will be pulled over the various configurations and inclinations of the ice surface with and without snow cover, if possible. The following observations should be made:

   - ease of pulling the sled over the ice and snow,
   - performance of the sled runners,
   - force required to pull the sled on the flat surface of the ice and snow expressed by the number of persons or measured with a dynamometer or spring balance,
   - location of towing rings, etc.

5. The sled will then be brought back on board the ship and carefully inspected for any damages and leakages. Their reasons should be determined. Then the sled will be located within the range of the ship crane and will be dropped into the water from a height equal to the deck on which it should be stowed. This test will be repeated three times, each time with the sled positioned in a different way relative to the water surface. The ship crane will be used each time to retrieve the sled from water. At the end of these tests the sled will again be inspected for any damages.

6. All of the tests will be video taped.

All of the crew members involved in the described before tests will wear immersion suits to reflect the likely situation during ship abandonment and, particularly since it will make all or most of the sled handling activities more difficult.

Functional Test Report: Sheet 1 of 7

Program Element: Moving the sled into position on the deck

Requirements:

The sled is to be moved from storage and transported to a suitable place on the deck. Observations to be recorded during this operation included:

- problems with handling of the sled on board the vessel,
- number of persons involved.

Observations:

a) The sled was manhandled, by up to six persons, from the helicopter hangar to the ship's side in way of the crane. Several pipes were placed under the sled and it was easily moved/rolled over the deck. The whole process took about one minute.

b) Physically lifting the sled was difficult due to a lack of handholds and its heavy weight. At about 750 lbs the sled is too heavy for ease of handling.

c) When the sled was rolled through the hanger doors there was contact between the sleds side and side latches and the door support structure. The result was some damage to two side latches. The damage was easily repaired with a large pair of pliers and a small pry bar.

d) When in the ready position all latches were tightened evenly such that they could still be opened quite easily.

e) One latch was found to be missing completely. The crew were unaware of where it might be. All tests were completed without this latch and no attempt was made to replace the latch or substitute some other means of closure.

Functional Test Report: Sheet 2 of 7

Program Element: Launching the sled into water

Requirements:

By means of a crane or a landing boom the sled is to be launched overboard into water and secured at the ship side. Observations recorded during this operation will include:

- problems with handling of the sled on board the vessel,
- number of persons involved,
- time required for launching the sled,
- safety considerations.

Observations:

a) Six crew members volunteered for the duties involved in towing the sled through the water and over the ice. They donned their immersion suits, taking about five minutes to complete the exercise. These suits were of the one-size-fits-all type and were uncomfortable for those with a smaller frame. The undersoles of the suit were covered with a reinforcing pad designed, presumably, for abrasion resistance rather than for traction on an ice or snow surface.

b) A work barge was chosen to tow the sled through the surrounding ice cover since it has an air cooled engine which is not susceptible to overheating due to the propeller being clogged with ice. In addition, the barge could be, and was, used more roughly than would a lifeboat, imposing a more rigorous test on the sled. The ship's officers were of the opinion that the lifeboat could easily marshal the sled and would simply tow it more cautiously.

c) The sled was picked up by the crane, using a simple rope sling, swung over the side and lowered gently to the water. No difficulty was experienced and the operation took about three minutes (including arranging the sling).

d) Once in the water the sled was freed from the crane hook and the sled towing lines were retrieved and held by crew on the work barge.

Functional Test Report: Sheet 3 of 7

Program Element: Towing the sled through water and pack ice

Requirements:

The sled is to be towed through the surrounding water and both open and closed pack ice. Observations will focus on:

- handling of the sled while towing,
- ease of manoeuvring,
- stability of the sled,
- resistance to collisions with ice,
- efficiency of the closing arrangement, etc.

Observations:

a) A towing rope was attached at each side of the sled with a bridle connecting the upper and lower towing lugs (i.e. on each side). Each towing rope was lifted on board the work barge using boat hooks, and attached to bollards.

b) The work barge accelerated through the water (free of any ice) to a speed of about six or eight knots, easily towing the sled. The sled generally took up a crabbed attitude to the work barge, i.e. leading with one of the corners. A small bow wave was created with made the forward draft slightly less then the half depth. At slower speeds the sleds draft was in the range of 20 cm to 30 cm. Except for the crabbing attitude of the sled there were no difficulties in open water towing.

c) Manoeuvring the sled was not difficult although it swung wider than the work barge at times.

d) When the sled encountered broken ice pieces it reacted by bouncing over or off the ice. Small pieces had little effect, larger pieces deflected the sled upwards and to the side. Very large pieces caused the sled to ride up over the ice, at times lifting the sled completely out of the water. On one occasion, the sled contacted a very large ice piece with only one side (runner). The effect was to tip the sled so high on one side that it flipped over (i.e. through 180°).

e) Overall, the sled was very stable when manoeuvred through ice. While it was bounced around it only tipped over once (due to a very large ice piece).

f) A second bridle towing arrangement was tried, i.e. one bridle attached to the lower port and starboard towing eyes, linked to the work barge by one rope. The result was to create a more stable motion in the sled, eliminating the crabbing attitude. In addition, the sled turned more tightly with the barge rather than swinging wide. Overall, this is a much preferred towing arrangement.

Functional Test Report: Sheet 4 of 7

Program Element: Pulling the sled onto an ice floe

Requirements:

After disembarking onto an ice floe, the lifeboat crew is to try to pull the sled onto the ice. First attempts will be made with as few persons as possible, if not successful, more persons will be used. Observations were to include:

- main reasons for difficulties in pulling the sled onto the ice,
- height of the ice above sea level,
- time required to retrieve the sled,
- number of persons involved,
- needs for supporting equipment, etc.

Observations:

a) The sled was easily pulled onto a large floe. First a single person attempted to lift/pull the sled onto the ice, and almost succeeded - the sled was 50 percent out of the water before it became too difficult and was allowed to slide back. A second person joined the first and easily pulled the sled onto the ice.

b) The action of transferring the sled onto the ice was largely pulling and partially lifting.

c) The traction offered by the undersoles of the immersion suit was quite good, resulting in very little slipping under foot - even while pulling the sled out of the water.

d) The character of the ice edge was quite varied (in freeboard). It ranged from negative (the edge below water) to about 0.30 m. There were no high freeboard areas. The pull-out tests were done with 0.2 to 0.3 m ice freeboard.

e) It took less than two minutes to evacuate the barge (onto the ice) and pull the sled out of the water.

Functional Test Report: Sheet 5 of 7

Program Element: Towing the sled over ice and snow

Requirements:

While on the ice, the sled is to be pulled over the various configurations and inclinations of the ice surface with and without snow cover, if possible. The following observations will be made:

- ease of pulling the sled over the ice and snow,
- performance of the sled runners,
- force required to pull the sled on the flat surface of the ice and snow expressed by the number of persons or measured with a dynamometer or spring balance.

Observations:

a) The sled could be pulled by two men with little difficulty over flat ice with hard snow cover, even over slightly rough or undulating terrain. The sled runners moved easily over the hard packed snow with no visible adhesion. Only when the sled was pulled through a small melt pool, wetting the runners, was any additional drag noticed. However, these were so infrequent and could be avoided so that it was not a problem.

b) The coefficient of friction (effective) was probably in the range of 0.05 to 0.1 (assuming a one person pull of 50 to 100 lbs and a sled weight of 900 lbs). Once it was moving, the sled was very easy to keep moving.

c) The sled could quite easily be pulled and pushed over rough ice conditions. The team was organised with four at the front pulling (two each side) and two behind pushing. In this way the sled could be moved over ice ridges and rubble, which was about 1.50 m in height with continuous changes in profile. Some difficulty was found when moving the sled up a long slope - at one point becoming stopped with all volunteers straining to move it forwards. This problem could be overcome by developing an appropriate sled handling technique.

d) Other than this one event, no problems were found in these quite rough ice conditions. The sled could be moved at a fast walking pace or faster if the crew chose to.

e) While the sled can probably be lifted vertically off the ice by four to six people, this was never required or attempted. The potential traction problems with the immersion suit undersoles may make such a lift dangerous. I may be that in very rough ice it would be necessary to lift the sled but, more likely, a technique would be developed which relied on partially lifting, pulling and pushing.

Functional Test Report: Sheet 6 of 7

Program Element: Retrieving the sled from the water (and inspection after the towing tests)

Requirements:

The sled is to be brought back on board the ship and carefully inspected for any damages and leakages. If found, their reasons will be determined.

Observations:

a) The ship's crane lowered the hook to the level of the top of the floating sled. A boat hook was used to retrieve the bridles and ropes at the towing end of the sled and these were slipped onto the hook. This took about one minute to accomplish.

b) The crane then lifted the sled out of the water (end first) and up to the helicopter deck.

c) The sled was opened easily. No damage had occurred to the latches and each could be opened with bare hands - and with more difficulty with gloves on. Opening these latches with immersion suit gloves (one piece) was very difficult - the opening lever is too small and snuggly fits into the sleds side. A latch should be found which allows the use of a gloved hand.

d) The top half of the sled was lifted/tilted off and onto the deck beside the bottom half. The lift was attempted by two people, assisted by one or two others. The seal did not break easily, but did after a few tries. Insufficient care was taken when tilting the top half over onto the deck resulting in the top half falling on its side, breaking off one of the latches (snapping it off completely).

e) Leakage had occurred only in the end compartment which had been facing forward during towing. This compartment is triangular in shape with a peak at the bottom. This peak had about 50 mm of water in it. All other compartments were completely dry.

f) There was no visible damage to the seals, nor to the sealing bars. Presumably there is some uneveness in the seal material or the bearing bar or the latches at that end were not sufficiently tight. The sled was not subjected to a water head of pressure, only to a bow wave of a few centimeters. This implies a very loose mating surface between seal and bearing bar.

g) The top half was lifted back onto the bottom half and, after some difficulty caused by the latches, it was resealed. The difficulty was due to not opening out (to the side) each latch, with the result that some of them get caught on their mating pieces thus preventing closure. This was easily adjusted.

h) Since the drop tests were to follow, care was taken to close the latches snuggly but still allowing them to be opened without difficulty. They could have been closed more tightly but that would make opening the sled more difficult.

i) Overall, opening and closing the sled (separating the halves) was found to be cumbersome due to the weight. Each half weighed about 170 kgs. With four lifters, each lifting about 45 kgs, it is difficult to manoeuver the top half off and onto the deck. If it only had to be lifted and directly placed onto the deck, it would be relatively simply, but flipping the sled so that the runners are on the deck was cumbersome. It may have been better to just place it directly on the deck then carefully roll it over onto the runners. However, this could damage the latches as it is rolled onto its side.

j) Damage had occurred to the paint on several of the forward parts of the sled (due to ice impact). None of this was serious and no physical damage (dents) were observed.

Functional Test Report: Sheet 7 of 7

Program Element: Drop tests

Requirements:

The sled is to be dropped into the water from a height equal to the deck on which it would be stowed. This test is to be repeated three times, each time with the sled positioned in a different way relative to the water surface. The ship's crane is to be used each time to retrieve the sled from water. At the end of these tests the sled is again to be inspected for any damages.

Observations:

a) The sled was rigged with bridles at each end so that it could be lifted in several ways (bottom down, side down and end down). The bridles were connected by a short rope loop attached to the crane hook and, when the sled was lifted it could be released by simply cutting the single loop, i.e. a man leans out from the ship's side and cuts it with a knife.

b) First, the sled was lifted, bottom down, over the side and lowered to a height of about 10 m above the water. The loop was cut, allowing the sled to drop into the water. The sled floated away from the ship's side (right way up). All latches remained closed and there was no visible damage.

c) The work barge retrieved the sled and returned it to the ship in way of the crane hook, reconnected the bridles at one end to the hook and allowed the sled to be lifted back up onto the deck.

d) The bridles were rearranged to lift the sled, side down, back over the side to the same height as before. The loop was cut and the sled dropped into the water. Initially it floated on its side but after about 30 seconds it turned onto its bottom. All latches remained closed and there was no visible damage.

e) Once more the sled was retrieved, returned to the ship and lifted on board.

f) The bridles were rearranged to lift the sled, end down (the end with both latches intact and in which leakage had previously occurred), back over the side to the same height as before. The loop was cut and the sled dropped into the water to a draft equal to about one half of the length of the sled, i.e. about 1.5 m. It floated on its bottom and all latches remained closed and there was no visible damage.

g) Once more the sled was retrieved from the water and returned to the helicopter deck for inspection.

h) On inspection it was found that no damage had occurred to the structure, latches or seals and no additional leakage was found. The same amount of water remained in the end compartment and all other compartments were completely dry.